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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 494

HAZARDS TO AIRCRAFT DUE TO ELECTRICAL PHENOMENA

Report of
Special Committee on Hazards to Aircraft
Due to Electrical Phenomena

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INTRODUCTION

In response to request of Rear Admiral Ernest J. King, U.S.N., Chief of the Bureau of Aeronautics of the Navy Department, dated July 8, 1933, the National Advisory Committee for Aeronautics established a special committee to consider the general question of hazards to aircraft, both airships and airplanes, due to electrical phenomena and make recommendations as to what should be done to insure the least hazard to aircraft from such phenomena. This special committee was composed of the following members:

Dr. Charles F. Marvin, Weather Bureau, Chairman,
Dr. L. J. Briggs, Bureau of Standards,
Commander Garland Fulton (C.C.), U.S.N.,
Dr. W. J. Humphreys, Weather Bureau,
Dr. J. C. Hunsaker, Massachusetts Institute of Technology,
Mr. G. W. Lewis, National Advisory Committee for Aeronautics (ex officio),
Dr. F. B. Silsbee, Bureau of Standards,
Professor John B. Whitehead, Johns Hopkins University.

This report presents the conclusions of this special committee. The report was first drafted, on the basis of a general discussion of the problem at a meeting of the special committee held on December 21, 1933, by a subcommittee consisting of Professor Whitehead, Chairman, and Doctor Silsbee, assisted by Dr. M. F. Peters, of the Bureau of Standards. Revisions were then made in the draft to conform to the comments of the other members of the special committee.

The report of the special committee was approved by the National Advisory Committee for Aeronautics on February 27, 1934, and was transmitted to Admiral King in response to his request.

SCOPE OF THE REPORT

The Special Committee on Hazards to Aircraft Due to Electrical Phenomena addressed itself particularly to the letter of Admiral King, dated July 8, 1933, and to the two types of electrical hazards to aircraft mentioned therein, viz., electrostatic attraction to earth and high-frequency discharges. These two hazards have been frequently suggested as the most dangerous. Estimates as to the magnitudes of their causes and their effects vary over a wide range. The results of the discussion on these questions at the meeting of the committee held on December 21, 1933, are given below. During the discussion many other aspects of the general electrical hazard were discussed and the conclusions of the committee on some of these are also included.

ELECTROSTATIC ATTRACTION OF AIRSHIP TO THE EARTH

It was generally agreed that an attractive force of this character cannot reach dangerous proportions. Two types of such forces were considered:

(a) The electrically conducting portions of the structure of an airship in the electric field between clouds and earth would permit the separation of negative charges on the upper surfaces and positive charges on the lower surfaces of the airship by the ordinary process of electrostatic induction. If, owing to any cause, the negative charge were dissipated or removed, there would be an attraction between the remaining positive charge and the earth.

Dr. G. C. Simpson, of the British Aeronautical Research Committee, has estimated the magnitude of this charge as being only a few hundred pounds and therefore unimportant. This figure is based on the gradient, usually found just preceding lightning discharge in thunderstorms, of 100,000 volts per meter. No suggestion is made in Doctor Simpson's analysis of the method in which the negative charge might be removed. The committee was in general agreement as to Doctor Simpson's estimate of the order of magnitude of this type of force. There was some opinion that in extreme cases the field intensity might rise to higher values than that assumed by Doctor Simpson. Nevertheless, allowing a factor of even two or three or more at this point, it was agreed that resulting attractive force to the earth would not rise to dangerous values.

(b) The possibility of the accumulation of higher values of electrostatic charge, due to continuous positively charged rain was also reviewed. It was recognized that under continuous rain a large positive charge might be accumulated provided all of the charge in the rain was retained by the airship. It was agreed that such accumulation could not take place. Estimates were reported of the total charge contained in a layer of rain water of the maximum thickness which might be retained by the airship's surface. The magnitude of the electrostatic charge of the average raindrop is known. It was agreed that the passing off of the excess water would also carry with it the corresponding charge. Then on this basis, it was concluded that the maximum attractive force to the earth would be about the same order of magnitude as that computed for the induced charges as reported above and consequently of insignificant magnitude.

(c) Evidence was presented showing that an airship in flight may accumulate an electrostatic charge. This is evidenced by a discharge between mooring ropes and earth as the airship descends. The effect has been noticed in electric shock to the man grasping the mooring rope. Such shocks, however, have not been fatal, thus indicating that the magnitude of the effect is not great.

It was also agreed that it is highly improbable that an airship can accumulate any considerable charge, first owing to the many exposed metallic points of short radius of curvature facilitating discharge, and particularly to the highly ionized condition of the exhaust gases from the engines.

HIGH-FREQUENCY OR STEEP WAVE FRONT LIGHTNING DISCHARGES

(a) It was agreed that the metal framework of either an airplane or an airship presents a high degree of internal protection against the effects of lightning discharges. The degree of protection is greater the more nearly the approach to the Faraday cage. Thus, for example, an all-metal airplane is safer than one in which wood and fabrics are used. In the airship the protection is greater the closer the meshes of the metallic framework, the wire bracing, and the wire netting enclosing the gas bags, and particularly the more highly electrically conducting the surface of the outer envolope.

(b) Airplanes: A number of reports of damages by lightning to airplanes in flight were reviewed, notably those in the article by H. Köppe (reference 1). It was generally agreed that it is possible, without serious complication, to render an airplane practically immune to serious danger either to the airplane or to the occupants. Exception to this conclusion was noted as regards radio antennas. If trailing in stormy weather the antenna may be burned off by a lightning discharge, or radio equipment inside the airplane may be destroyed. Simple protective measures against each of these hazards are available.

(c) Airships: The fact that the outer surface of an airship is nonconducting electrically and that the metal framework, wire bracing, and wire netting of the airship have meshes of definite area, has led to the suggestion that high-frequency disturbances might penetrate to the inside of the airship setting up sufficiently high values of electrical potential difference to cause discharges and consequent damage. Two possibilities are indicated: First, that for a discharge through the metal structure of the airship of a steep wave front (corresponding to short wave length as compared to dimensions of the airship) potential difference due to the passage of current through the metal framework may cause differences of potential between the different parts of the airship; second, that a direct stroke to the airship might actually enter the area of the open mesh between the airship members, passing to some electrically conducting member inside the outer framework.

As a particular case involving possible extreme hazard, it was suggested that condensation of water on the inner surfaces of the gas bags might constitute an interior electrical conductor which might receive a direct or indirect stroke due to a high-frequency disturbance. It was suggested that such stroke would puncture the gas bag electrically, leading to leakage and possible destruction. Evidence of the possibility of this type of disturbance was limited to the well-known behavior of electric circuits under high-frequency resonance disturbance, in which large differences of potential and at times electric discharges are observed between points on a continuous metallic member which has relatively short longitudinal radius of curvature.

(d) The committee was agreed as to the possibility of some degree of penetration of electrical influence arising in this way within the region inside the outer envelope of the airship. There was general doubt, however, as to whether it could rise to dangerous magnitudes. No evidence was available that electrical disturbances arising outside the airship have ever been observed inside. The opinion was advanced, and apparently accepted, that if internal disturbances of this character and of serious proportions could arise, some evidence of them would have been manifested in past experience.

(e) The committee was agreed also that protection against such possible high-frequency disturbances would be relatively simple by such close approach as would be necessary to the principle of the Faraday cage. Obvious measures would be: giving electrical conductivity to the outer envelope by incorporating conducting ingredients or by the use of conducting paints; reducing the spacing of metallic members and of the wire bracing; protection of gas bags by wire mesh or other conducting screens.

(f) The committee does not find sufficient evidence of the existence of disturbances of this character to warrant a recommendation of a program of experimental study.

TRAILING ANTENNA AND OBSERVER'S SUSPENSION CABLE

(a) Antenna: There is good evidence that a trailing antenna during a thunderstorm increases the likelihood that a lightning discharge will take place through the body of the airplane or airship. It is commonly agreed that the antenna should be withdrawn under stormy conditions. It was also agreed that if operated under such conditions it is possible to limit resulting damage to the antenna itself and to the radio equipment connected therewith.

(b) Observer's cables: Suspension of an observer from an airship involves a cable much longer and larger than the usual antenna. The action of such cable in facilitating a lightning discharge would be correspondingly greater. Aside from this fact, however, and its possible consequence on the airship itself, it was generally agreed that no great additional hazard for the observer is likely, provided the latter is housed in a metallic cage. The danger of a rupture of the cable through fusion by electric arc was considered to be very remote.

STORM AREAS SHOULD BE AVOIDED

The foregoing report notes the evidence of electrical charges and discharges from the structures of both airplanes and airships. The committee considers the probability small that serious damage will result from discharges when trailing antenna and cables are reeled in and when the customary protective methods inherent in bonded metallic cage construction are utilized. But even though neither airplanes nor airships of proper construction are in much danger from lightning, both must make every effort to avoid thunderstorms - must keep out of the exceedingly violent and extremely turbulent winds of thunderstorms which cause great danger of destruction.

Respectfully submitted.

SPECIAL COMMITTEE ON HAZARDS TO AIRCRAFT DUE TO ELECTRICAL PHENOMENA,

C. F. Marvin, Chairman.

Washington, D. C., February 27, 1934.

REFERENCE

1. Koppe, Heinrich: Practical Experiences with Lightning Discharges to Airplanes. T.M. No. 730, N.A.C.A, 1933.